A Random-Scan Display of Predicted Satellite Positions

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CONTENTS

ABSTRACT

With the completion of the NRL evaluation of the experimental model of the Satellite Position Prediction and Display equipment (SPAD), efforts have been directed toward the design of an operational version of SPAD. Possible design and equipment configurations have been proposed which would lead to a substantial savings in cost and reduced equipment complexity. These designs involve the displaying of the SPAD information by means of a random scanning of the display area, thus allowing a large reduction in the circuitry associated with the display generator. Another advantage of this method is that the computer-display buffer memory, which stores all of the information for display, can be incorporated into the computer. Although this requires a higher speed computer than would otherwise be necessary, the amount of external circuitry would be greatly reduced and the overall reliability increased. Another possible alternative is to adapt SPAD for use in a Naval Tactical Data System (NTDS). This would be particularly useful if an NTDS facility is available for use by SPAD.

PROBLEM STATUS

This is an interim report; work on the problem is continuing.

AUTHORIZATION

NRL Problem Y01-01
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A RANDOM-SCAN DISPLAY OF PREDICTED SATELLITE POSITIONS

INTRODUCTION

With the evaluation of the prototype version of the Satellite Position Prediction and Display equipment (SPAD) nearing completion, some consideration has been devoted to the design of an operational version of SPAD. Several alternative systems have been conceived which would present a display that would appear the same as is presented in the first-generation SPAD, but would be generated in a different manner which would result in a reduction of the electronic circuitry. One method which would provide considerable circuit reduction is to present the data on the display by means of a random scan, which is referred to in this report as a jump scan.

After giving a brief description of how the display is generated in the original SPAD equipment, this report will describe in some detail the possible alternatives and requirements for an operational version of SPAD using the jump-scan type of display.

GENERATION OF DISPLAY CYCLE USED IN FIRST-GENERATION SPAD

In the prototype version of SPAD, the generation of each display frame on the cathode-ray tube (crt) utilizes the combination of a television (TV) interval and a jump-scan (JS) interval. During the TV interval a raster is generated for painting the map grid lines, position dots, orbit points, and area of view. During the JS interval, symbol groups are randomly painted to identify the satellite, own ship, and map grid lines.

When operating in either the world map or the rectangular expanded mode, a TV type of raster consisting of 361 noninterlaced lines is generated. The parallels of the map grid are painted by brightening the appropriate sweep lines, while the meridians are produced by applying short video pulses at the appropriate places along each sweep line. Thus this type of raster can easily produce the map grids shown in Figs. 1 and 2. For the polar display a sweep is used which consists of 361 radial lines originating at the center of the display, with the first and last sweep lines coinciding. The polar map grid is produced, as shown in Fig. 3, by a method similar to that previously described for the world map and the rectangular expanded displays. However, in the polar display the meridians are painted by brightening entire sweep lines, while the parallels, which appear as concentric circles, are painted with short video pulses along each sweep line.

The satellite and own-ship position dots are generated on the same raster and by digital logic timing signals similar to those used for painting the map grid lines. Thus the relative locations of the positions and the map grid lines will not be affected by any drift, distortion, or hysteresis in the analog deflection circuitry. The main advantage of using the combination raster and jump-scan display is that a high degree of accuracy can be obtained while using a display with a fairly low positioning accuracy. The theory of the generation of this type of display is given in greater detail in Ref. 1.

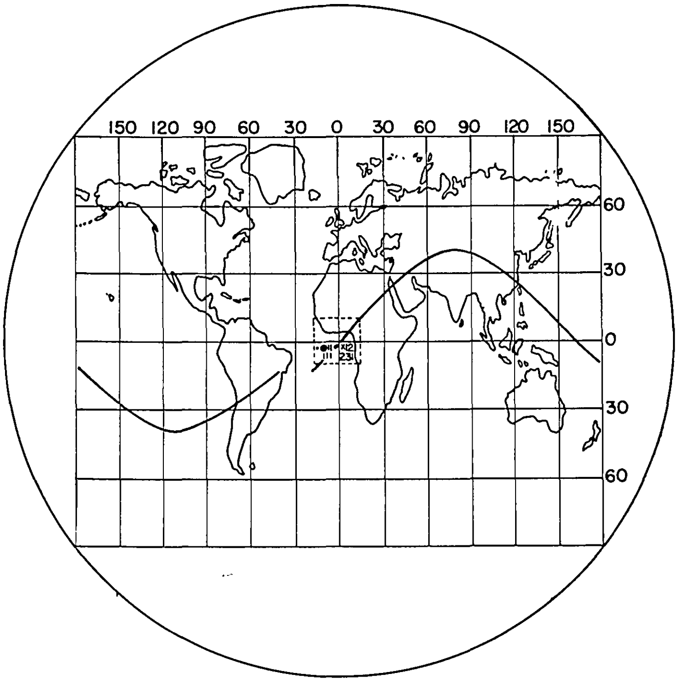

Fig. 1 - Appearance of world map display

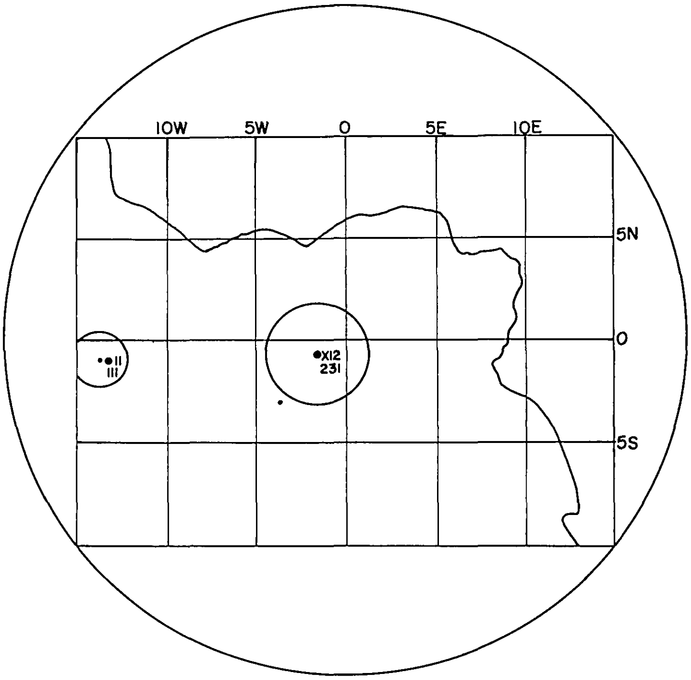

Fig. 2 - Appearance of rectangular expanded display

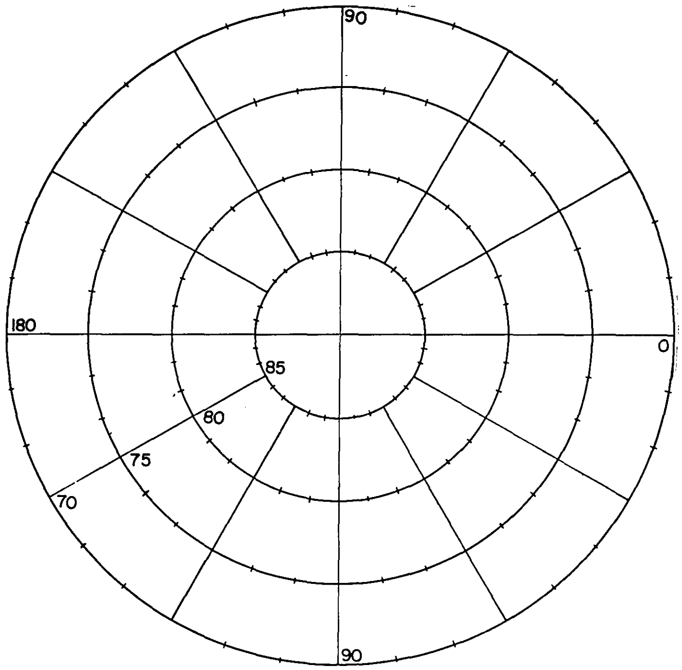

Fig. 3 - Appearance of polar expanded display

THE JUMP-SCAN DISPLAY

The use of an all-jump-scan display eliminates the sweep generators that were necessary to provide the raster. Also eliminated are the counting circuits which controlled the sweeps and the digital comparators for generating position dots (see Ref. 1). Besides the reduction in circuitry, the speed requirements for the display can also be reduced. In the first generation SPAD, much time was consumed in scanning the display where no information was being painted. In maintaining a display rate of 30 frames per second, the display spent 73 μsec on each raster line with a horizontal sweep recovery time of 11 μsec, plus a random position settling time of 22 μsec for painting each symbol group. Using the all-jump-scan display, the world map display consists of a total of 415 symbols, vectors, position dots, and orbit points (see Appendix A). Thus for 30 frames per second, or 33.3 msec per frame, there is about 80 μsec available for generating each of these elements on the display.* This allows the use of a much slower deflection circuitry than was required in the first-generation SPAD.

The jump-scan painting of the orbit points permits the displaying of an orbit with much better resolution, while at the same time using less memory space to store the orbit points. In the first-generation SPAD the orbit points were quantized to 4 degrees in both latitude and longitude and by encoding of the orbit words, required a memory of 350 words of 18 bits each. By painting the orbit with the jump-scan technique, the resolution of point positions can be increased to 0.5 degree in latitude and 1 degree in longitude to produce a smoother more pleasing curve. This technique would still require only 128 words of memory to store 128 points. While 18 bits per word would be necessary for specifying the actual position, more bits would be required so that the display could identify the word as

*The 80 μsec is not realistic since certain elements could be painted in much less time, thus allowing the use of a higher frame rate.

being an orbit point. Even if word lengths of 30 bits were used, the total number of bits to store an orbit would be less than was required in the first-generation SPAD.

The state of the art in displays has progressed far enough so that adequate accuracy can be obtained on a modern display by using the jump-scan method for generating the displayed information. Displays can reportedly be obtained with repeatability accuracies for random positioning of about ±0.08 in. on a 21-in. rectangular crt. To show that this would be adequate for a SPAD display, consider the world map presentation. On a 21-in. crt, the size of the world map could be about 12 by 16 sq in. A positioning error of ±0.08 in. would then correspond to an error of ±1.9 degrees in longitude and even less in latitude. With the map grid lines painted at 30-degree intervals, as shown in Fig. 1, the operator could not be expected to interpolate positions closer than ±3 degrees. Therefore a positioning accuracy of ±1.9 degrees would be more than adequate for this situation. In the case of the rectangular expanded display (Fig. 2), which uses the same size display area on the crt as for the world map, the maximum positioning error would be ±0.15 degree. With the map grid lines placed at 5-degree intervals, this error is still less than the accuracy for which the operator could be expected to reliably interpolate positions

REQUIREMENTS FOR THE COMPUTER-DISPLAY BUFFER

The functions of a computer-display buffer are to accept and store all data words sent from the computer, permanently store fixed information such as map grid lines and their identifying symbol groups, and read out to the display the appropriate data words at a rate such that the display will have no apparent flicker. A frame rate of 30 frames per second is the minimum that can be allowed and a higher rate is preferred. Sixty frames per second would be the ideal rate because then the display cycle can be synchronized with the ac line frequency to avoid beat effects.

The SPAD computer-display buffer must be capable of storing approximately 533 words of 30 bits each (see appendix B). There are several devices which could be used to store these words, such as microcircuit flip-flops, delay lines, and magnetic core memories. The main disadvantage of flip-flops and delay lines are their volatile nature, which means that whenever power is either lost or turned off, their contents are destroyed. This means that data cannot be stored permanently in these types of stores. The magnetic core memory would be the most practical solution for storing data of this type and magnitude, since the contents are not destroyed when power is off.

The physical size of the buffer unit should be kept as small as possible. It would be preferable for the buffer to be located in the same cabinet as the display, thus eliminating a separate equipment enclosure and shortening the cable runs to the display. The actual circuit design would depend on the type of computer and display that are selected. The buffer would also have to perform the proper voltage conversion of the digital logic levels between the computer and the display.

INCORPORATING THE COMPUTER-DISPLAY BUFFER INTO THE COMPUTER

When going to an all-jump-scan display, the computer-display buffer is reduced to a unit which has functions similar to the input-output operations of a general purpose computer. Therefore, the possibility arises of incorporating the buffer into the computer. Thus the buffer memory would actually be a part of the computer's memory, and the transferring of data words to the display would be handled by the computer program. Of course the speed and memory capacity of the computer must be increased over what would otherwise be necessary, but there would be a savings in external equipment requirements.

The speed of the computer must be fast enough so that it can completely update the display at least 30 times per second and still have time to perform the necessary prediction computations and service the input requests from the computer control panel which will be discussed later. The memory would have to be increased so that it could store all the data that was required of the buffer, plus the additional program steps that are required to execute these extra operations which would be assigned to the computer.

There are two methods the computer could use in carrying out its required operations: (a) it could read out a whole display frame of data to the display and then perform its prediction computations until the time comes to read out a new display frame, or (b) it could interleave the computations with the readout to the display. The first method would require a higher speed display since only part of each display frame interval would be available for generating the display. It is anticipated that the programming of the computer would be easier because the readout to the display would be a part of the program and would always occur at the same locations in the program. For instance, it may be possible to perform one complete satellite position computation between successive readouts to the display. The second method has the advantage of using a slower speed display since the entire display frame is available for generating the display. It appears that this method would be superior to the first even though it might complicate the computer program to some extent. However, this would also depend on the type of computer being used. With the second method it would probably be more convenient to have the display determine the display cycle by requesting new data words from the computer as they are needed.

Having the computer take the place of the computer-display buffer may not necessarily lead to the most economical SPAD system, but it would simplify the equipment which is external to the computer and should reduce the maintenance and increase the overall reliability.

REQUIREMENTS FOR THE DISPLAY

The purpose of the display and its associated circuitry is to accept digital data either from the computer-display buffer or directly from the computer and produce the displays, as shown in Figs. 1 - 3, at the request of the operator.

The display must include some type of character generator for producing the symbol groups. The actual method used for generating the characters is not of particular importance here since most any of the commercial generators would be satisfactory. The symbols that are needed for the SPAD display consist of ten numbers (0 through 9), the letters E, W, N, S, and the 17 special-purpose category symbols shown in Fig. 4. This makes a total of 31 characters, which means that five bits would be adequate for selecting them.

The display must also be capable of generating vectors for the map grid lines on the world map and the rectangular expanded displays. Given the digital positions of the starting and ending points, the display must connect the points with a straight line. Usually the length of each vector is limited to some value such as one-fourth of the display diameter. It would be desirable for the vector generator to be capable of stringing groups of vectors to form a continuous line by simply supplying new end points, with the display retaining the starting point. Thus, after the initial vector has been generated using two data words, each successive vector is generated with only one additional data word. This feature would reduce the number of data words that have to be stored for generating the map grid lines.

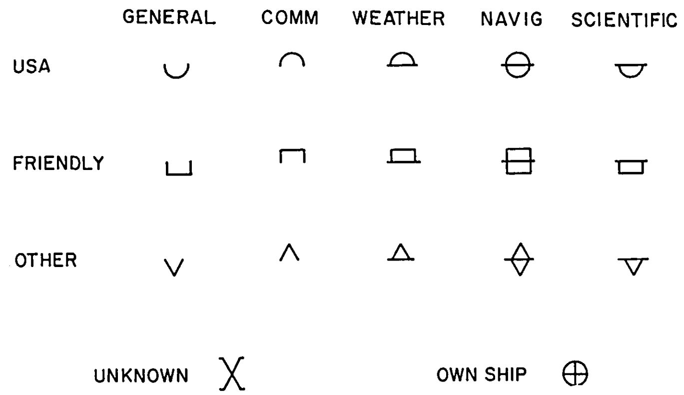

Fig. 4 - Special-purpose category symbols used in SPAD display

The vector generator would also be used for displaying the viewing area of a satellite. Because of the convergence of the meridians at the poles, the viewing area cannot be represented on the world map and the rectangular expanded display as a circle. Therefore, a polygon, say with 20 sides, has to be used as an approximation. Thus the computer will have to compensate for the convergence of the meridians in its calculation of the location of the points of the polygon. On the polar expanded display, the problem is simplified because the viewing area can be represented as a circle.

To generate the polar map grid, a circle generator should be included in the display equipment to generate the four concentric map grid circles as shown in Fig. 3. The required inputs to the circle generator would be the position of the center of the circle and the circle radius, all in a digital format. The circles could be approximated by using a series of straight-line segments. However, this would degrade the appearance of the display and would involve the storage of many more data words.

These requirements are well within the state of the art of display equipment, and many off-the-shelf displays can offer the features described above as standard options.

COMPUTER CONTROL PANEL

The computer control panel provides a means for the operator to communicate with the computer. With this panel, the operator can make selections such as which satellites are to be displayed, the prediction time, and the map scale. These operations of the control panel are given in detail in Ref. 2.

From the evaluation of SPAD at the NRL installation, the computer control panel, as shown in Fig. 5, was judged to be satisfactory. Therefore, no change in its operations or capabilities are recommended for future versions of SPAD. However, it is possible that not all SPAD installations would need all of the features that are included in the original control panel.

One possible change that could be made in the circuitry, but which would not change its features of operation, is to use the computer interrupts in different ways. In the first-generation SPAD, 10 separate computer interrupt lines were used, each line denoting the particular type of request that was being sent to the computer. If the SPAD computer was to be used by other systems in addition to the SPAD display, then some of these interrupts may have to be assigned for use by the other systems. To facilitate this possibility, the computer control panel could be revised slightly so that only one interrupt line would be

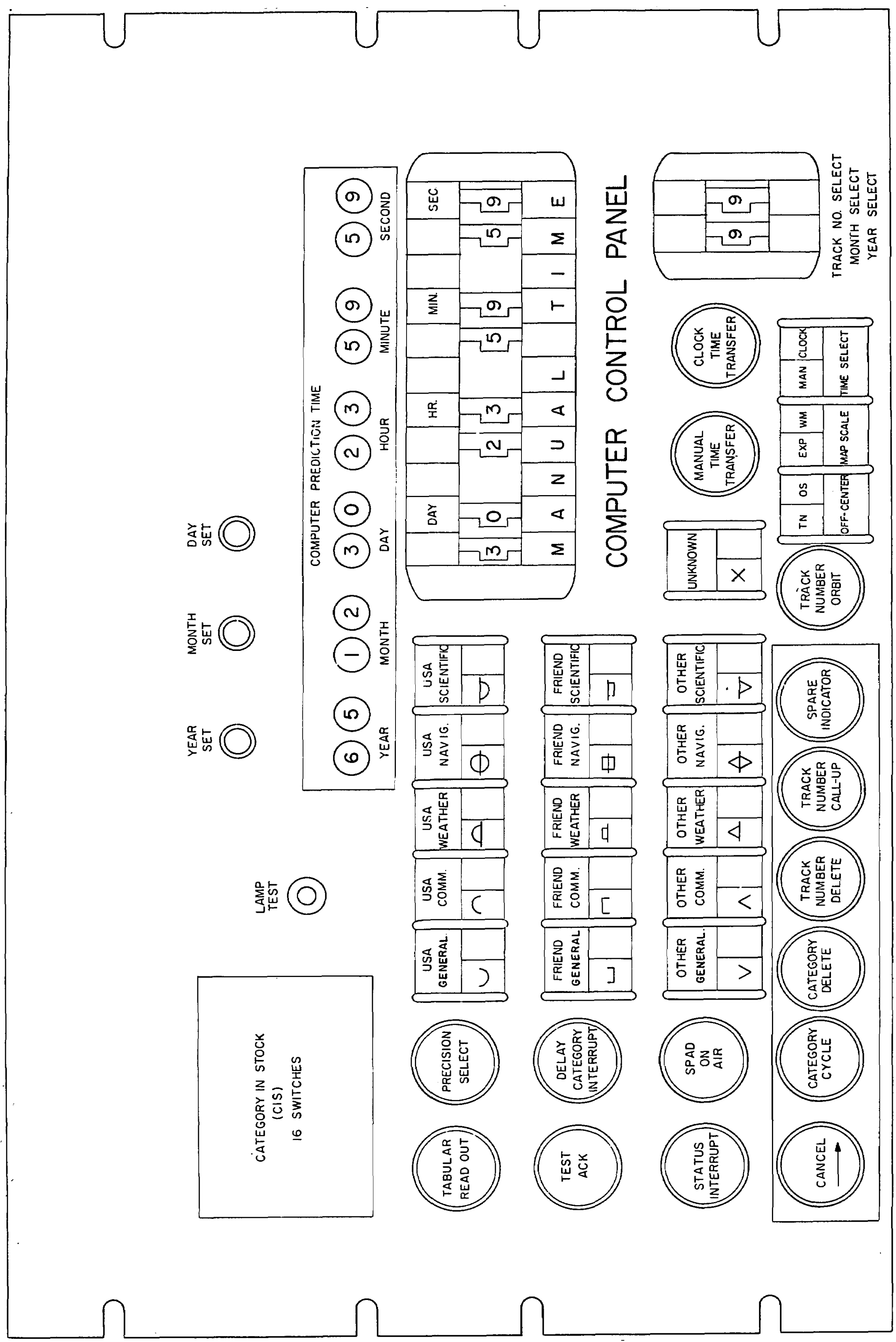

Fig. 5 - Computer control panel sketch

needed by the SPAD equipment. The actual computer request could be selected by coding several bits of the computer input data word. At the present time, this is the only circuit change that can be anticipated.

The most significant change that can be made is the repackaging of the electronics associated with the control panel. The switch to integrated circuits can lead to a large reduction in the size of the logic circuitry. Small size is a necessity because the panel must be mounted in whatever space is available close to the display crt so that it is within easy reach of the operator.

OWN-SHIP DATA AND REAL-TIME INPUTS

The own-ship data is a required input to the SPAD equipment and must be supplied from some external source. In particular, own-ship's position, heading, and speed are needed for displaying the ship's position along with a symbol group to designate speed and heading. The ship's position is also needed by the computer for computing antenna pointing angles should this feature be desired. These antenna pointing angles, as computed by the original program, do not take into account the ship's deck movement or heading. Therefore, some external unit must supply correction factors to these angles before they can be sent to the antenna steering controls. Reference 3 presents more information on how these pointing angles are computed.

The preferred source of the own-ship data would be the ship's navigational equipment. The data would be sent either at regular intervals or at the request of the computer. If the own-ship data cannot be obtained directly from the navigation equipment, a special own-ship data panel can be constructed, as was done in the first-generation SPAD, to allow the manual entry of this data by the operator. This method was adopted in the original SPAD equipment because the evaluation was performed at a shore installation. Although this is not the preferred method, it could be used as an expediency in a shipboard installation.

Besides the own-ship data, real time is also a required input to SPAD. For reasons of accuracy and reduced circuitry, the ideal source for real time would be the ship's master clock, if such a unit is available. If not, a real-time generator can be built into the SPAD equipment as was done in the original version of SPAD. A tuning fork oscillator was used as the stable frequency source, and countdown circuits were provided for obtaining the seconds, minutes, and hours. Each time the power is turned on, the clock is set to the correct time by entering the time on thumb wheel switches, and then transferring this into the clock using time signals from WWV as the standard time reference. This feature could be included as standard equipment in a SPAD installation. Then, except for weekly time checks, SPAD would not be dependent on an external source for its real time.

ONE POSSIBLE SYSTEM CONFIGURATION

To obtain an estimate of the magnitude of a complete SPAD installation, one possible SPAD configuration will be discussed. The proposed equipment will have its display generated directly from the computer at a rate of at least 30 frames per second. This will require a computer with a higher speed and larger memory than the AN/UYK-1, which was used in the original version of SPAD. The AN/UYK-3, with its high-speed input/output (I/O) option, could provide all of the necessary SPAD functions. This computer is three times faster and contains up to four times the memory space over that of the AN/UYK-1. Since the programming of the AN/UYK-1 is compatible with the AN/UYK-3, much of the original SPAD program could be used with this higher speed computer. For the SPAD installation, the AN/UYK-3 would require an I/O controller such as the BR-141, which includes a tape reader, punch, and typewriter. Although the tape punch and typewriter are not used for normal operation of SPAD, they would be needed if the conversion of the satellite orbital elements into the SPAD format is carried out on the SPAD computer. (See Ref. 3 for this conversion process.) This would probably be necessary if there are only a few SPAD installations in existence. However, if enough SPAD installations were in operation, then this conversion process would probably be done at one selected location.

A commercial display console that could be used with the AN/UYK-3 to present the SPAD information is manufactured by Information Displays, Inc. (IDI). Their standard speed M10000 Dualflec display, along with the circle, vector, and high-speed character generator options, can provide all of the functions that are required of a SPAD display. It must be pointed out that there are many displays on the market that could just as easily satisfy the SPAD requirement, so the IDI display is mentioned just to give an example of a display that would be adequate. This display can furnish the options listed above, along with the proper mode control for selecting these options and with the circuitry for interfacing with the AN/UYK-3.

In addition to the display and the computer, the computer control panel must be added to the display console. As mentioned earlier, the control panel would have the same general configuration and functions of the original SPAD, but it would be repackaged using integrated circuits to reduce the size. It is estimated that by using integrated circuits the computer control panel, with all of its associated logic circuitry and power supply, can be mounted on a standard 19-in. rack panel, 12.5 in. high and 12 in. deep. This does not include the circuitry to provide the own-ship inputs and the real-time input. These circuits may add slightly to the size, depending on the form in which this data can be obtained on the ship.

A tabulation of the size, power, and weight for the complete SPAD installation is shown in Table 1. Even though there may be other SPAD configurations which would be slightly lower in cost, this still gives a good indication of what is involved in a SPAD installation.

Table 1
Tabulation of Size, Power, and Weight of
a Proposed SPAD Installation

	Volume (ft^3)	Power (watts)	Weight (lb)
IDI M10000 Display	30	500	560
Computer Control Panel	2	210	80
AN/UYK-3 Computer	14	2000	600
BR-141 Controller	14	2032	500
Total:	60	4742	1740

SPAD ADAPTED FOR NTDS

Another alternative that should be mentioned here is the adaptation of SPAD for use in an NTDS system. A study is just beginning on the feasibility of using an NTDS computer and display for presenting SPAD information. At the present time it appears that there are no big technical problems involved in utilizing NTDS for SPAD. The NTDS equipment would probably have to be augmented with the SPAD computer control panel, since any existing control panel would not have all of the special-purpose features of the SPAD control panel. In addition, provisions must be made for entering own-ship data and real time as described earlier, unless these inputs are already tied into the NTDS equipment. A new computer program would also have to be written for the NTDS computer.

It appears that the inclusion of SPAD into NTDS would be worthwhile if SPAD is to be put on a ship that already has an NTDS system, and if time is available for the NTDS system to handle the additional functions of SPAD on a time-shared basis.

If there was a requirement for the NTDS displays and the SPAD display to be operated simultaneously, a separate display console could probably be installed for the SPAD display, with both displays using the same NTDS computer on a time-shared basis. The adaptation of SPAD into NTDS offers some promising advantages, and more study is being carried out in this area to determine exactly what modifications and cost would be involved.

CONCLUSIONS

While more study is necessary to make a recommendation for the exact SPAD configuration, the use of an all-jump-scan display is definitely recommended. The savings in circuitry that is made possible by this method far outweigh any of its possible deficiencies.

A proposed SPAD configuration has been presented in detail. This is not necessarily the optimum system, but it serves to provide an indication of the size and cost of a SPAD installation.

Another possible approach is to adapt SPAD for use in an NTDS facility. This seems to offer many advantages and study is continuing on this approach.

ACKNOWLEDGMENTS

Assisting in the planning and preparation of the material presented in this report were H.G. Talmadge, R.J. Orsino, and T.L. Francavilla.

REFERENCES

1. Orsino, R.J., and Boller, J.R., "SPAD Formatter: Satellite Prediction Computer – Display Interface," NRL Report 6431 (in publication)
2. Talmadge, H.G., Jr., and Orsino, R.J., "Operation and Performance of the NRL Satellite Position Display," NRL Report 6219, Aug. 1965
3. Orsino, R.J., and Francavilla, T.L., "Prediction Equations for the NRL Satellite Position Display," NRL Report 6396, Aug. 1966

Appendix A

NUMBER OF DISPLAY ELEMENTS FOR VARIOUS DISPLAY MODES

A. Display requirements for world map display:

Symbols for map grids, satellites, and own ship	168
Vectors for two 20-sided circles	40
Vectors for map grid	67
Position dots for satellites and own ship	12
Position dots for orbit points	128
Total elements to be displayed	415

B. Display requirements for rectangular expanded display:

Symbols for map grids, satellite, and own ship	60
Vectors for two 20-sided circles	40
Vectors for map grid	41
Position dots for satellite, vector, and own ship	3
Total elements to be displayed	144

C. Display requirements for polar expanded display

Symbols for map grids, satellite, and own ship	60
Circles for area of view	2
Vectors for map grid	24
Circles for map grid	4
Position dots for satellite, vector, and own ship	3
Total elements to be displayed	93

Appendix B

NUMBER OF 30-BIT WORDS TO BE STORED BY COMPUTER-DISPLAY BUFFER

Orbit points	128
Satellite and own-ship positions	12
Map grid symbol group positions (World Map)	16
Map grid symbol group positions (Rectangular Expanded)	8
Map grid symbol group positions (Polar Expanded)	8
Satellite and own-ship symbol groups	12
Map grid symbol groups (World Map)	16
Map grid symbol groups (Rectangular Expanded)	104*
Map grid symbol groups (Polar Expanded)	8
Satellite vector	1
Vectors for two 20-sided circles	42
Vectors for map grid (World Map)	87
Vectors for map grid (Rectangular Expanded)	53
Vectors for map grid (Polar Expanded)	34
Circles for map grid (Polar Expanded)	4
	533

*Only 8 of the 104 possible symbol groups are displayed at once; however all are stored in the buffer.

NOTE: At any one time the map grid vectors of either the world map, the rectangular expanded, or the polar expanded displays are painted.

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13. ABSTRACT

With the completion of the NRL evaluation of the experimental model of the Satellite Position Prediction and Display equipment (SPAD), efforts have been directed toward the design of an operational version of SPAD. Possible design and equipment configurations have been proposed which would lead to a substantial savings in cost and reduced equipment complexity. These designs involve the displaying of the SPAD information by means of a random scanning of the display area, thus allowing a large reduction in the circuitry associated with the display generator. Another advantage of this method is that the computer-display buffer memory, which stores all of the information for display, can be incorporated into the computer. Although this requires a higher speed computer than would otherwise be necessary, the amount of external circuitry would be greatly reduced and the overall reliability increased. Another possible alternative is to adapt SPAD for use in a Naval Tactical Data System (NTDS). This would be particularly useful if an NTDS facility is available for use by SPAD.

14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Satellites (Artificial)						
Display Systems						
Classification						
Computers						
Computer Storage Devices						
Data Storage Systems						
NTDS (Naval Tactical Data System)						
SPAD (Satellite Position Prediction and Display)						

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There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, roles, and weights is optional.